

**INTEGRATION OF BUILDING INFORMATION
MODELLING (BIM) WITH MATERIALS
MANAGEMENT IN CONSTRUCTION PROJECT**

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INTEGRATION OF BUILDING INFORMATION MODELLING (BIM) WITH
MATERIALS MANAGEMENT IN CONSTRUCTION PROJECT

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DEDICATION

I dedicate this thesis to my late father; Hussein Fayed Mogalli and my mother Aliyah Ali. I also, dedicate this work to my beloved wife, brothers, sisters and my entire family members.



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All praise is to Allah the highest, the provider of opportunities to all creatures. I thank Him for giving me strength, health and inspiration to accomplish my Master project report writings. It is verily a great pleasure to have successfully completed this study.

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ABSTRACT

Construction industry in Malaysia still lags behind other industries in terms of implementation of information technology. Materials management needs adequate consideration in complex construction projects due to the involvement of several elements of project. Hence, late delivery of materials can lead to delay that gives negative impact to overall project plan especially in schedule. BIM is considered as an effective way to solve the problems in the construction project life cycle. Therefore, the objectives of this research were to identify the challenges of BIM integration with materials management and to study the potential of BIM integration with materials management in construction project. This research focuses on the integration of BIM with materials management in construction project at Kuala Lumpur with G7 contractors involved and consultants. The quantitative (questionnaire) approach was used to gain information from consultants and contractors (G7). There were 304 copies of questionnaires distributed to the targeted respondents and 93 of the response were collected which was 30.59 % of total respondent. The data were collected and analysed using Statistical Package for Social Science (SPSS) version 21.0. The findings showed that, most of respondents agreed that lack of awareness, unavailability of data formats, lack of introducing and lack of understanding of BIM as challenges of BIM integration with materials management in construction project. Similarly, most of respondents agreed that BIM can integrated for planning and scheduling, controlling and monitoring, supply chain and storage of materials management as potential of BIM integration with materials management in construction project. The research finding encouraged the consultants and contractors in Malaysian construction project should understand BIM, knowledge of BIM and awareness of BIM in order to integrate BIM with materials management in construction project.

ABSTRAK

Industri pembinaan di Malaysia masih tertinggal jauh berbanding industri lain dari segi pelaksanaan teknologi maklumat. Pengurusan bahan memerlukan pertimbangan yang memadai dalam projek-projek pembinaan kompleks kerana penglibatan beberapa unsur-unsur projek. Oleh itu, penghantaran bahan yang lewat boleh mengakibatkan kepada penangguhan yang memberi kesan negatif kepada perancangan projek keseluruhan terutamanya dalam penjadualan. BIM merupakan cara yang berkesan untuk menyelesaikan masalah-masalah dalam kitar hayat projek pembinaan. Oleh itu, objektif kajian ini adalah untuk mengenalpasti cabaran integrasi BIM dengan pengurusan bahan dan mengkaji potensi integrasi BIM dengan pengurusan bahan dalam projek pembinaan. Kajian ini tertumpu kepada integrasi BIM dengan pengurusan bahan dalam projek pembinaan di Kuala Lumpur dengan kontraktor G7 yang terlibat serta juru perunding. Pendekatan kuantitatif (soal selidik) telah digunakan untuk mendapatkan maklumat daripada juru perunding dan kontraktor (G7). Sejumlah 304 borang soal selidik telah diedarkan kepada responden dan 93 maklum balas telah dikumpulkan dimana merupakan 30.59% daripada keseluruhan responden. Data yang dikumpul dianalisis dengan menggunakan *Statistical Package for Social Science* (SPSS) versi 21.0. Dapatan kajian menunjukkan bahawa, sebahagian besar daripada responden bersetuju bahawa kurangnya kesedaran, ketiadaan format data, kurangnya hebahan maklumat, dan kurangnya pemahaman BIM sebagai cabaran integrasi BIM dengan pengurusan bahan dalam projek pembinaan. Begitu juga, kebanyakan responden bersetuju bahawa BIM boleh bersepadu untuk perancangan dan penjadualan, pengawalan dan pemantauan, rantai bekalan dan penyimpanan pengurusan bahan sebagai integrasi BIM yang berpotensi dengan pengurusan bahan dalam projek pembinaan. Dapatan kajian menggalakkan perunding dan kontraktor dalam projek pembinaan Malaysia bagi memahami BIM, pengetahuan BIM dan kesedaran BIM dalam usaha untuk mengintegrasikan BIM dengan pengurusan bahan dalam projek pembinaan.

TABLE OF CONTENTS

TITLE	i
DECLARATION	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF ABBREVIATION	xiii
CHAPTER 1 INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	3
1.3 Research Questions	6
1.4 Research Objectives	6
1.5 Significant of Research	6
1.6 Research Scope	7
1.7 Research Methodology	8
1.8 Thesis Outline	10
1.9 Summary	11
CHAPTER 2 LITERATURE REVIEW	12
2.1 Introduction	12
2.2 Materials Management in Construction Projects	12
2.2.1 Materials Management Overview	13
2.2.2 Materials Management Processes	13
2.2.2.1 Planning	14
2.2.2.2 Procurement	15
2.2.2.3 Handling	16
2.2.2.4 Stock and Waste Control	16
2.2.2.5 Logistic	17

2.2.3	Materials Management Problems	17
2.2.4	Technologies in Materials Management	18
2.3	Building Information Modelling (BIM)	19
2.3.1	Definition of BIM	20
2.3.2	The Concept of BIM	22
2.3.3	Characteristics of BIM	23
	2.3.3.1 Digital Databases	23
	2.3.3.2 Change Management	24
	2.3.3.3 Reuse of Information	25
2.3.4	BIM Tools	25
2.4	Integration of BIM with Materials Management	27
2.4.1	Construction Management with BIM	27
2.4.2	Information Management with BIM	28
2.4.3	Performance Management with BIM	29
2.5	Benefits of Integration BIM with Materials Management	29
2.5.1	Technological Support	30
2.5.2	Support for Enhancing Data Quality	30
2.5.3	Support for Coordination and Integration of Process	31
2.5.4	Collaboration for Materials Management	31
2.6	Challenges of BIM with Materials Management	32
2.6.1	Lack of Awareness of BIM with Materials Management	32
2.6.2	Knowledge and Understanding of BIM with Materials Management	33
2.6.3	Lack of Unavailability of BIM with Materials Management	33
2.6.4	Interoperability of BIM with Materials Management	34
2.6.5	Communication of BIM with Materials Management	34
2.6.6	Coordination of BIM with Materials Management	34

2.7	Summary	35
CHAPTER 3 RESEARCH METHODOLOGY		36
3.1	Introduction	36
3.2	Quantitative Research Approach	36
3.2.1	Questionnaire Design	37
3.2.2	Population and Sampling	37
3.2.3	Pilot Survey	39
3.3	Data Collection	39
3.3.1	Literature Review	41
3.3.2	Questionnaire Survey	41
3.4	Questionnaire Data Analysis	42
3.5	Summary	43
CHAPTER 4 DATA ANALYSIS AND DISCUSSION		44
4.1	Introduction	44
4.2	Distribution and Retune of the Questionnaire	44
4.3	Data Analysis Method	45
4.3.1	Cronbach's Alpha for Reliability Statistics	45
4.3.2	Frequency and Descriptive Analysis	45
4.4	Reliability Test	46
4.5	Respondents Background	47
4.5.1	Position	47
4.5.2	Type of Projects	48
4.5.3	Working Experience	49
4.5.4	Number of Projects Completed	50
4.5.5	Software Use for Materials Management	51
4.5.6	Software Use in Company	52
4.6	Challenges of BIM Integration with Materials Management in Construction Project	54
4.6.1	Discussion of Finding	56
4.7	Potential of BIM Integration with Materials Management in Construction Project	57
4.7.1	Discussion of Finding	59
4.8	Summary	61

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS	62
5.1 Introduction	62
5.2 Summary	62
5.2.1 Objective 1: Challenges of BIM Integration with Materials Management in Construction Project	63
5.2.2 Objective 2: Potential of BIM Integration with Material Management in Construction Project	63
5.3 Contribution to Knowledge	64
5.4 Limitation of Research	64
5.5 Recommendations	65
5.5.1 Recommendation to Construction Industry	65
5.5.2 Recommendation to Future Research	66
5.6 Concluding Remarks	66
REFERENCES	67
APPENDICES	77
APPENDIX A QUESTIONNAIRE	78
APPENDIX B VITA	84



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF TABLES

2.1	Definition of BIM from Individuals/Organizations	20
2.2	BIM Construction Management and Scheduling Tools (Reinhardt, 2009)	26
4.1	Questionnaire Distribution and Return	45
4.2	Cronbach's Alpha Coefficient (Zikmund <i>et al.</i> , 2010)	46
4.3	Reliability Test Result	46
4.4	Position in Organisation	48
4.5	Type of Projects	49
4.6	Working Experience	50
4.7	Number of Projects Completed	51
4.8	Software Use for Materials Management	52
4.9	Software Use in Company	53
4.10	Challenges of BIM Integration with Materials Management in Construction Project	55
4.11	Potential of BIM Integration with Materials Management in Construction Project	58

LIST OF FIGURES

1.1	Research Methodology Flow Chart	9
2.1	Alternative Emphases in Construction Planning (Hendrickson, Chris, 1998)	15
2.2	Conceptual Diagram to Describe the Building Information Modelling (Haron <i>et al.</i> , 2009)	23
3.1	Research Process	40
4.1	Position in Organisation	48
4.2	Type of Projects	49
4.3	Working Experience	50
4.4	Number of Projects Completed	51
4.5	Software Use for Materials Management	52
4.6	Software Use in Company	53

LIST OF ABBREVIATION

BIM	Building Information Modelling
PWD	Public Works Department
CIDB	Construction Industry Development Board
API	Application Programming Interface
GDP	Gross Domestic Product
CSV	Comma Separated Values
AECO	Architecture, Engineering, Construction and Operation
SBM	Single Building Model
PLM	Product Lifecycle Management
GIS	Geographic Information System
IFC	Industry Foundation Classes
KPL	Key Performance Indicators
SPSS	Statistical Package for Social Science



CHAPTER 1

INTRODUCTION

This chapter outlines the discussion on the research background and statement of the research problems. The discussions formulate the research questions and research objectives. Furthermore, significance of research, scope of research and brief methodology considered is also discussed. Finally, this chapter provides outlines of thesis as well as the summary of the study and summary.

1.1 Research Background

Construction projects by nature are fragmented, complicated, risky and uncertain. These challenges are arguably exacerbated in construction projects which have their unique problems, caused mainly by the remoteness of the project itself, resulting in the loss of control over communications and management including lack of management skills, human resources and infrastructure (Arayici *et al.*, 2012). There are some problems around communication; coordination and management occur especially in remote construction projects in which stakeholders are all located in discrete locations or even in different countries. Sidawi (2012) and Yang *et al.*, (2007) proposed advanced computer based management systems for effective information management and communication since conventional technologies are seen as not capable of meeting required processes and project improvements for the construction projects. The project team has to not only tackle traditional management problems but those that specifically occur as a result of the remote locations of these often environmentally sensitive sites (Kestle 2009; Kestle & London, 2003; Sidawi, 2012). The sites are often far from logistic support, suffer a continuous shortage of materials, and specialized labor (Kestle & London, 2003).

Building Information Modelling (BIM) based design and construction processes for efficient and effective management of construction projects are required for appropriate material management systems and design cost information, specifically in remote construction works (Arayici *et al.*, 2012). BIM is one of such technology innovations and represents the process of development and use of a computer generated model to simulate the planning, design, construction and operation of a facility in a virtual environment (Gardezi *et al.*, 2013). In Malaysia, BIM had been introduced by the Public Works Department (PWD) since early 2007 (Latiffi *et al.*, 2013). The establishment of a BIM Committee within PWD had supported the exploration of BIM by PWD. The purpose was to identify a suitable BIM platform that could be used by PWD. The committee proposed to use Autodesk as one of the BIM tools. The use of the tool was proposed through the information technology department. Subsequently, by the end of 2010, installation of the BIM tool started in PWD, followed by the training in using the tool in early 2011 (Latiffi *et al.*, 2015). Moreover, BIM unit project was established in May 2012, which consists of architects, structural engineers, mechanical and electrical (M&E) engineers as well as quantity surveyors. The pilot projects are Type 5 Clinic (KK5) Sri Jaya Maran, Pahang and administration complex of Suruhanjaya Pencegah Rasuah Malaysia (SPRM) Shah Alam, Selangor (Latiffi *et al.*, 2015).

In construction projects, due to the confined nature of the construction site, the site layout and material management plan have to be carefully coordinated in order to ensure a smooth workflow (Said & El-Rayes, 2013). Incorrect deliveries and storage of materials on site without use can take place of the workspace in construction projects. Long travel distances between material deliveries and projects in actual time, double handling of materials and overcrowding of the site due to improperly coordinated deliveries due to a lack of planning (Said & El-Rayes, 2014). Material management with BIM can linked to the construction schedule to create a resource-loaded schedule. The resource-loaded schedule is used to estimate the consumption of materials, and forms the basis for planning the materials management of material delivery and storage in construction project (Cheng & Kumar, 2015).

Therefore, this research will need for managing the information properly to ensure all parties in the construction projects receive the right information and the utilization of Building Information Modelling (BIM) is one of the platforms to meet all objectives to integrate BIM with materials management in construction project.

1.2 Problem Statement

The construction industry in Malaysia has been identified as an important part in contributing to the Malaysian economy and contributes to approximately 3 to 5 % of the Gross Domestic Product (GDP) annually (CIDB, 2009). Although the Malaysian construction industry plays a significant role, contributing to the growth of country's economy, in the era of globalization the Malaysian construction industry needs more development in construction projects. The Malaysian construction industry must upgrade the current construction approach, whether in terms of practice, management or technology. Implementing the new information technology, especially Building Information Modelling (BIM) in the Malaysian construction can be utilized to increase the productivities and transforms to be more improving in construction industry (CIDB, 2009; Ibrahim *et al.*, 2010).

Construction contractors are increasingly engaged in supply of material from diverse sources around the world and statistics have declared that more than 65% of a construction project budget is spent on procurement of material (Ahmadian *et al.*, 2014). The procurement process emerged as a result of construction and engineering activities whereby it requires a profound investigation for efficient selection of construction materials. Late delivery of construction materials and components has been identified as one of the main causes of delay in major industrial construction. Therefore, timely delivery of materials is essential to ensure meeting completion date of construction activities projects (Fallahnejad, 2013). However, on time delivery of materials is a complicated job and requires planning, monitoring and control of different stages of the materials management including the transportation stage. Off-site transportation of materials has been estimated to account for 10 to 20% of the total project expenditure in typical industrial construction projects. However, despite its importance, little has been done to investigate the efficiency of the current

transportation management practice and potential strategies to improve it (Ahmadian *et al.*, 2014).

Materials management has been a problematic function for large and complex projects, where advanced tools and techniques are required. The management of materials in complex construction projects needs adequate consideration due to the involvement of various elements of project (Kasim *et al.*, 2013). Almost 50 to 60% of the total project cost is that of material and equipment required for the project, and unavailability of material and equipment delays the project (Ibironke *et al.*, 2013). Efficient material management is crucial to project success. Materials stock outs, incorrect storage of materials, double handling, inefficient methods, and out-of-sequence deliveries, have been observed as some of the most frequently occurring material management shortages on jobsites, which disrupts workflow, and decrease productivity (Thomas *et al.*, 2005). Hence, late delivery of materials can lead to delay that gives negative impact to overall project plan especially in schedule. With the use of BIM on construction projects the technological capabilities of vendors become increasingly important (Ocheoha & Moselhi, 2013). Hence, an effective materials management system is required in order to avoid problems, such as delays in a construction project. Many factors speed up the delay of project duration, however poor materials management can have a major effect on construction sites. Noted that the common problems relating to materials management are storage problems incorrect materials delivery, subsequent design changes, materials surplus, materials damage, incorrect materials take-off and vendor evaluation (Kasim *et al.*, 2013).

The use of IT-based tools such as BIM, supply-network visibility and accurate information concerning the status of materials management at different stages can be enhanced (Irizarry *et al.*, 2013). The BIM module automatically quantifies specific materials as soon as modelled into Revit and then exports the properties for objects selected by the user to a central database (e.g. MS Access). The same approach can be used in the different BIM platforms. The schedule date (e.g. consumption date) was extracted from the construction schedule, while detailed information about materials (e.g. weight, size) was obtained directly from the BIM model (Irizarry *et al.*, 2013). BIM is primarily a three dimensional digital representation of a building and its essential characteristics. It is made of intelligent building components, which includes data attributes and parametric rules for each

object. For example, a door of certain material and dimension is parametrically related and hosted by a wall. Furthermore, BIM provides consistent and coordinated views and representations of the digital model including reliable data for each view (Hergunsel, 2011).

Comprehensive planning of the construction site layout, monitoring of site level activities, and continuous coordination with material suppliers is extremely vital in materials management (Pryke, 2009). In urban construction projects, due to the confined nature of the construction site, the site layout and material management plan have to be carefully coordinated in order to ensure a smooth workflow in construction projects (Said & El-Rayes, 2013). The main issues are incorrect deliveries and stockpiling of materials on site lead to overcrowding of the workspace, large travel distances between material storage and construction project are common examples in construction projects because a lack of planning (Said & El-Rayes, 2014). Material information is extracted from the BIM model and linked to the construction schedule to create a resource-loaded schedule. The resource-loaded schedule is used to estimate the consumption of materials, and forms the basis for planning the logistics of material delivery and storage in construction projects (Cheng & Kumar, 2015). For example, arrange reinforcement is linked with the quantity of reinforcement from BIM model. Revit Application Programming Interface (API) to automatically extract these material quantities and link them with the schedule, which is store in the Comma Separated Values (CSV) format (Cheng & Kumar, 2015). Therefore, it is important to study the integration of BIM with materials management in construction projects to overcome the challenges that occur in the management of materials.

1.3 Research Questions

This research conducts to following questions:

- (i) What are the challenges of integration BIM with materials management in construction project?
- (ii) What is the potential of integration BIM with materials management in construction project?

1.4 Research Aim and Objectives

The aim of this research is to integrate BIM with materials management in construction project. To achieve the aim of the research, the following objectives have been identified:

- (i) To identify the challenges of BIM integration with material management in construction project.
- (ii) To study the potential of BIM integration with materials management in construction project.

1.5 Significance of Research

Construction industry is one of the most challenging in Malaysia. The challenges of construction industry are lack of innovation in technology, motivation, poor knowledge, soft-skills. Most of Malaysian construction firms still lacking on BIM implementation in construction project. BIM can be viewed as a combination of advanced process and technology that offers a platform for collaboration between different parties in the construction project by exploiting the uses of Information Technology (IT). The enhancement of BIM implementation in the Malaysian

construction industry is due to the positive effects of BIM applications in construction projects such as cost estimation, project scheduling, bring together all of the information about every component of a building in one place, make the project workflows more easily and use of BIM become even more clearly than it is in current projects. BIM technology provides a platform for each key construction player to have effective communication between practitioners before the construction starts. The implementation of BIM in the Malaysian construction industry is expected to increase due to its benefits in construction projects.

The finding from this research can be contributed new information and knowledge in materials management within integration of BIM in construction project. The study purposes to identify the challenges of BIM integration with materials management and study the potential of BIM integration with materials management in construction project. It enhances and provides the practitioners who involve in construction project to know more knowledge and information technology skills about integration of BIM with materials management in construction project.

1.6 Scope of Research

The scope of this research is focused on the integration of BIM with materials management in construction project. The research is to identify the challenges of BIM integration with materials management in construction project and study the potential of BIM integration with materials management in construction project.

The research focused on the integration of BIM with materials management in construction project at Kuala Lumpur (Azhar *et al.*, 2012), that is due to Kuala Lumpur is more developing city in Malaysia, also need to be developed in many stages by using BIM in construction projects. This research focused on the respondents as consultants and contractors; in order to obtain the integration of BIM with materials management in construction projects (Sambasivan & Soon, 2007). G7 employ many professional such as huge number of sub-contractors, workforce and specialists in their projects. According to Ismail *et al.* (2014), G7 contractors are the higher capability in implementing and adopting BIM in construction projects.

1.7 Research Methodology

To accomplish the research objectives, a research method was adopted. In the adopted research, method includes literature review, academic research journals, dissertations, textbooks, articles and the internet. The selected relationship between research methods and output of related activities is show in Figure 1.1. Literature review is the previous studies, which were conducted to compare identifying the challenges of BIM integration with materials management in construction project, and study the potential of BIM integration with materials management in construction project. The methods used was questionnaire survey and data collection was based on the respondents' background, identify the challenges of BIM with materials management in construction project and study the potential of BIM with materials management in construction project and further data collection is analysed using SPSS software.



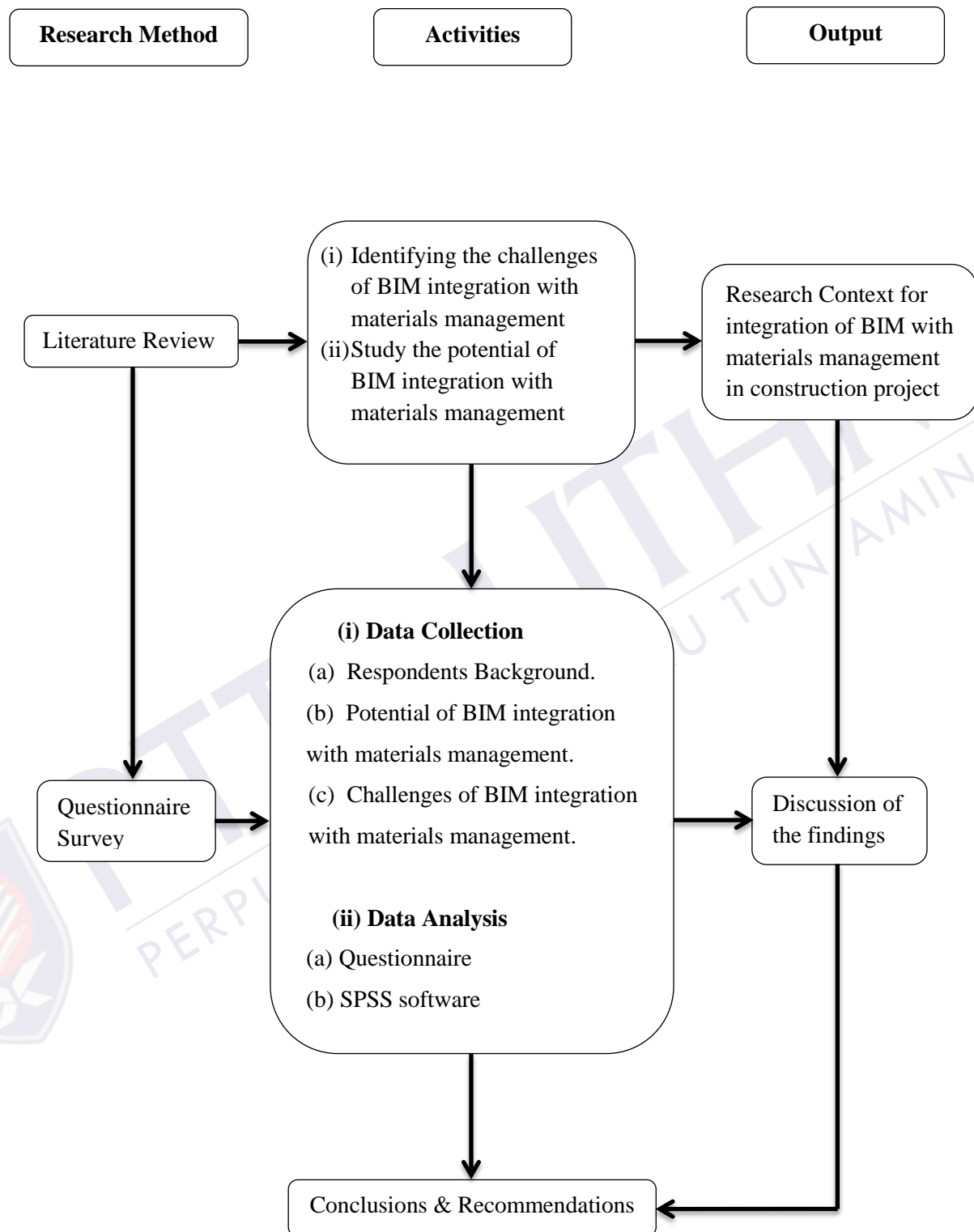


Figure 1.1: Research Methodology Flow Chart

1.8 Thesis Outline

The thesis consists of **FIVE (5)** main chapters. The chapters' organizations are as follows:

(i) Chapter 1: Introduction

This chapter consists of introduction to research, background of research, problem statement, research questions, research aim and objectives, significance of research, scope of research, research methodology and thesis outline.

(ii) Chapter 2: Literature Review

This chapter discussed on BIM in construction project including its definition, benefits as well as challenges of BIM integration with materials management in construction projects.

(iii) Chapter 3: Research Methodology

This chapter discussed on research approaches and strategies, and research procedures to be used as well as the process of both data collection and analysis of research were developed.

(iv) Chapter 4: Data Analysis and Discussions

This chapter explains the analysed of data from questionnaire survey and further discussed in detail of data analysis and findings was highlighted accordingly.

(v) Chapter 5: Conclusion and Recommendations

In this chapter, conclusion was drawn out and the limitations of the research were highlighted. Furthermore, this research discussed the finding and provides recommendations for future research.

1.9 Summary

This chapter has identified the challenges of integration of BIM with materials management in construction project. Furthermore, the potential issues of BIM integration with materials in construction project which are explained in problem statement that are standardization, issues in consumer perception, supply chain, technology, storage, planning and scheduling, controlling and monitoring of materials, incentive and communication issues. In this chapter, it also includes section of research questions, research objectives, significance of research, and scope of research, summarized methodology and structure of the thesis. The next chapter will focus on the literature review, which is the finding from previous researches.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The main aim of this chapter is to provide several discussions of literature review regarding the integration of BIM with materials management in construction projects. Material management is important to project success in construction. BIM has a positive impact on material deliveries, which enhances the benefits of implementation. Visualization using BIM helps clients and other project stakeholders to understand complex projects. Reduced uncertainty and improved predictability from the visualization of the construction project over time helps to ensure an uninterrupted workflow and increase productivity. BIM generates accurate material quantities and helps to ensure a reliable delivery schedule which is important during implementation (El-Omari & Moselhi, 2011).

2.2 Materials Management in Construction Projects

Materials management can be defined as a process of planning, executing, and controlling the right source of materials with the exact quality, at the right time and place suitable for minimum cost construction process. Capability to coordinate and integrate purchasing, shipping and material control from suppliers is required for material cost control (Madhavi *et al.*, 2013).

The management of materials in construction projects is an important function that significantly contributes to the success of a project. As projects grow in scale and complexity, materials management becomes more difficult, often requiring the use of appropriate tools and techniques to ensure, amongst other things, that

materials are delivered on time, stock levels are well managed, the construction schedule is not compromised, and that wastage is minimized (Kasim *et al.*, 2008). Materials management is especially problematic for large and complex projects, where sophisticated tools and techniques are necessary. The management of materials in complex construction projects needs adequate consideration due to the various elements involved and the importance of the project. Furthermore, the implementation of appropriate ICT could facilitate new management processes for complex projects. For example, the potential of emerging technologies such as wireless technologies and tagging technologies could have a strong impact on materials management processes in the future (Kasim *et al.*, 2008).

2.2.1 Materials Management Overview

Material management is a process for planning, executing and controlling the field and office activities in construction. The goal of material management is to ensure that construction materials are available at their point of use when needed. Material management is the system for planning and controlling all of the efforts necessary to ensure that the correct quality and quantity of materials are properly specified in a timely manner, obtained at a reasonable cost and most importantly, available at the point of use when required (Patel *et al.*, 2016). Effective construction materials management process is a key to success of a construction project. Costs for materials handling, may range from 30 to 80% of total construction costs. Therefore, there is a need for efficient materials management in order to control, productivity and cost in construction projects (Patel *et al.*, 2016).

2.2.2 Materials Management Processes

Materials management processes involve the planning, procurement, handling, stock and waste control, and logistics surrounding materials on construction projects. A good materials management environment enables proper materials handling on

construction sites. In order to better understand material management process initiates from need produced from site then this information conveyed to store department and material is ordered in the store (Kasim *et al.*, 2008). The following processes are discussed; planning, procurement, logistics, handling, stock and waste control.

2.2.2.1 Planning

Construction planning is a fundamental and challenging activity in the management and execution of construction projects. It involves the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks (Polekar, 2015). A good construction plan is the basis for developing the budget and the schedule for work. Developing the construction plan is a critical task in the management of construction, even if the plan is not written or otherwise formally recorded. In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project (Hendrickson & Chris, 1998). In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control as illustrated in Figure 2.1.

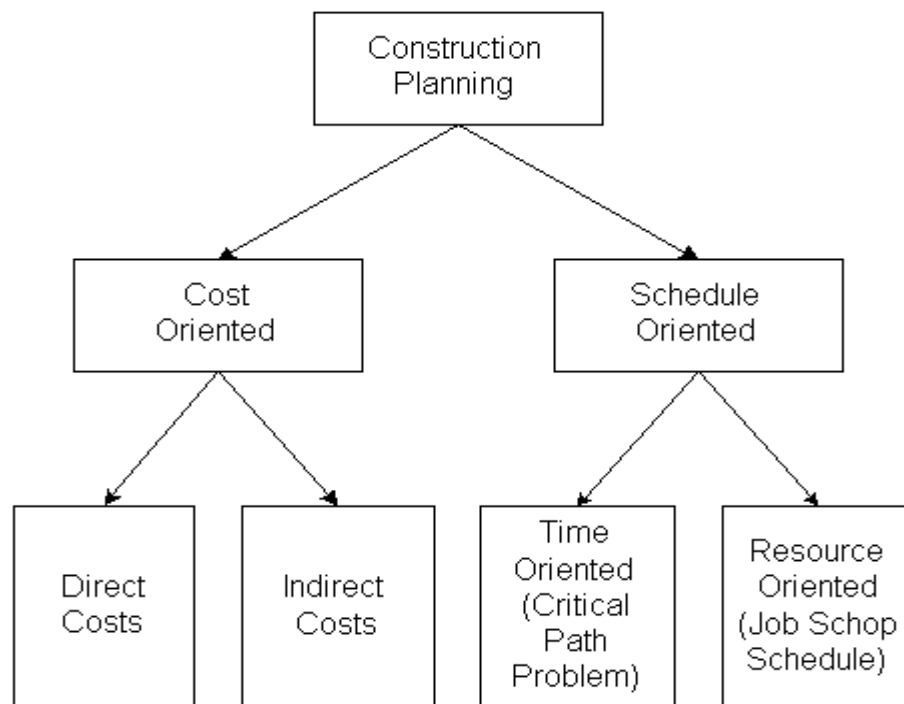


Figure 2.1: Alternative Emphases in Construction Planning (Hendrickson & Chris, 1998)

2.2.2.2 Procurement

Changes in customer expectations in the construction industry regarding project delivery, time, cost, and quality have forced the stakeholders to search for new operational models. Advances in non-construction industries in the areas of procurement and business management have improved the national productivity by an average of 2.7% per year from 1987 to 1996 and 3.9% per year from 1996 to 2002. The construction industry's productivity, however, has not followed suit. The productivity in the construction industry has only increased by a mere 0.2% per year from 1987 to 1996 and -1.0% from 1996 to 2000. One source of this static productivity increase in the construction industry is the procurement chain management system (Education, 2000). The current practice of procurement is no longer satisfying the market requirements. Due to the urgent need for improvement of the current construction procurement model, varieties of alternative models are being practiced throughout the industry.

2.2.2.3 Handling

Handling of materials is the flow component that provides for their movement and placement. The importance of appropriate handling of materials is highlighted by the fact that they are expensive and engage critical decisions. Due to the frequency of handling, materials there are quality considerations when designing a materials handling system (Kasim *et al.*, 2008). The selection of the material handling equipment is an important function as it can enhance the production process, provide effective utilization of work force, increase production and improve system flexibility. The materials handling equipment selection is an important function in the design of a material handling system in order to enhance the production process, provide effective utilization of manpower, increase production, and improve system flexibility (Dmitrovic *et al.*, 2002).

2.2.2.4 Stock and Waste Control

Stock control is a technique to ensure all items such as raw materials, processed materials, components for assembly, consumable stores, general stores, maintenance materials and spares, work in progress and finished products are available when required. Construction activity can generate an enormous amount of waste. There are also mentioned that construction materials waste, in the USA contributes approximately 29%. In the UK, it contributes more than 50% and in Australia, it contributes 20-30%. This is evidence to control constructions materials in a good way during the construction process (Kasim *et al.*, 2008). The cause of waste in construction projects indicates that waste can arise at any stage of the construction process from inception, right through the design, construction and operation of the built facility. Therefore, waste can be reduced through the careful consideration of the need for minimization and better reuse of materials in both the design and construction phases (Dainty & Brooke, 2004).

2.2.2.5 Logistic

Logistics is a concept that emphasizes movement and it encompasses planning, implementing, and controlling the flow and storage of all goods from raw materials to the finished product to meet customer requirements. Raw materials for construction are usually varied, bulky, heavy, and required proper handling in the supplying process. Consequently, the construction industry requires active movement of materials from the suppliers to the production area in both the factory and the worksite (Pheng & Chuan, 2001). The primary focus of the logistics concept in construction projects is to improve coordination and communication between project participations during the design and construction phases, particularly in the materials flow control process. They also mentioned that problems arise in the materials flow control process which includes delays of materials supply, due to some materials purchased just before they are required and waste of materials during storage, handling and transporting when procured in large quantities without complying with the production needs on site (Kasim *et al.*, 2008).

2.2.3 Materials Management Problems

There are many issues which contribute to materials management in construction projects such as waste, transport difficulties, improper handling on site, misuse of the specification, lack of a proper work plan, inappropriate materials delivery and excessive paperwork all adversely affect materials management (Kasim *et al.*, 2005). The delays in the construction industry are a global phenomenon and are considered as one of the most issues in the construction sector. That is why, the level of risk and uncertainty in the construction sector is on the higher side as compared to other sectors. In addition to the fact that the construction projects have complex and time consuming designs, the construction processes and methods are also subject to unprecedented events and circumstances. This has resulted in serious challenges and effect risk management has become a major problem that confronts the construction industry (El-Shekeil *et al.*, 2014).

Many problems in materials management occur in terms of purchasing and supply of materials such as not matching materials with the ordering purchase, forgetting ordering materials, over or less materials, early or late materials arriving, lack of actual time strategy, lack of training and adequate management, lack of communication and relation between contractor and supply chain companies are the main obstacles (Donyavi & Flanagan, 2009). Some common problems on construction site are more clearly, which are namely:

- Failure to order on time, which delays the projects.
- Delivery at the wrong time, which interrupts the work schedule.
- Over ordering.
- Wrong materials or error in direction of materials requiring re-work.
- Theft of materials from delivery into production.
- Double handling of materials because of inadequate material.

2.2.4 Technologies in Materials Management

There are various advantages in the implementation of ICT in materials management, as ICT has the potential to significantly improve the management of materials on site. ICT is used in materials management for cost estimating through involving well-known software such as Primavera and Microsoft Excel. However, there is not much use of modern ICT tools such as BIM and RFID to facilitate materials management processes in tracking materials easily, quickly and accurately (Kasim *et al.*, 2013).

With the development of information technology, many industries have greatly improved production efficiency. Building Information Modelling (BIM) is one of technologies implement with materials management for considered an effective way to solve the problems in the construction projects. The integrated BIM information is a significant improvement in all processes where project participants have to use and communicate complex, accurate and interrelated construction project information (Li & He, 2013).

2.3 Building Information Modelling (BIM)

Building Information Modelling (BIM) is a set of reactions between policies, processes and technology to produce a method for managing importance of building design and project data in digital format or virtual through the building life cycle (Penttilä, 2006). Hardin (2009) stipulates that BIM is not just a clever use of 3D models, but it also is making significant changes in workflow and project delivery process while NBIMS (2010) states that BIM as a tool for digital representation comprising physical characteristics and function of a facility. Thus in other words, BIM is a process of drawing and design, construction of a building by using technology approach, and it involves a procedure in Architecture, Engineering, Construction and Operation (AECO) (Abdullah *et al.*, 2014). BIM approach allows an object or model is defined in terms of elements and building systems such as space, beams, pillars and columns (Kymmell, 2008).

With the development of information technology, many industries have greatly improved their production efficiency. At the same time, production efficiency in the construction industry has not only failed to grow, but is actually on the decline. The main reason for this problem is interoperability, which is the exchange and sharing of construction project information between the participants and the different application software in the project life cycle. At present, BIM is considered an effective way to solve the problems in the construction project life cycle. The integrated BIM information is a significant improvement in all processes where project participants have to use and communicate complex, accurate and interrelated construction project information (Li & He, 2013). The degree of information sharing and collaboration of construction units is low, that is the main reason for low efficiency in the construction project. Then, a BIM-based information integration model is proposed. The information interchange of construction units is realised in this model. The efficiency of project management is improved (Li & He, 2013).

2.3.1 Definition of BIM

The modern definition of BIM has appeared in late 1990's - early 2000's, with the emergence on the market of a number of SBM (Single Building Model) realization concepts offered by different CAD software vendors, such as Revit, Autodesk and Bentley (Migilinskas *et al.*, 2013). BIM is an important knowledge in the industry of AECO (Succar, 2008). Consequently, several definitions have been given to its term in order to show the importance of BIM.

Table 2.1: Definition of BIM from Individuals/Organizations

Individuals/ Organizations	Definition of Building Information Modeling (BIM)
Amor and Faraq (2001)	A single project database that serves as a model for electronic data where all parties involved refer to it in the course of the design, construction, operation and maintenance.
Construct-IT (2002)	An nD model that combines various aspects of design information required at each stage of the life cycle of building facilities.
The Associated General Contractors of America (AGC) (2005)	The development and use of computer software model to simulate the construction and operation of a facility. Produced models are equipped with a variety of data, object-orientation, digital data representation of intelligent and parametric facilities, whose views and data needs of multiple users can be extracted and analysed to produce information that can be used to make decisions and improve process delivering building services.
American Institute of Architects, (AIA) (2007)	A project delivery approach that integrates people, systems, structures and practices in the process together and take advantage of the views of all stakeholders in order to optimize the production of projects, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction.
Kymell (2008)	BIM acts as a simulation project that consists of the components of 3D model of a project that has to do with all the necessary information relating to project planning, design, construction or operation.

Glick and Guggemos (2009)	A novel approach of project delivery to integrate people, systems, business structures and practices into collaborative processes to reduce waste and optimize efficiency through all phases of the project life cycle, which also supports the concept of Integrated Project Delivery (IPD).
National Building Information Modeling Standards (NBIMS) (2010)	A digital representation tools include physical characteristics and function of a facility. BIM also is a source of knowledge about the shared facilities as further information in order to form a solid foundation in determining the outcome of the building during its life cycle; defined as existing from the initial concept to demolition. A basic premise of BIM is collaboration of many different stakeholders at different phases of the life cycle of a facility to insert, remove, update or modify information in the BIM to support and reflect the roles of the various stakeholders.
Mastering Autodesk Revit Architecture (2011)	BIM refers to a 3D parametric model used to produce plans, sections, elevations, perspectives, details, schedules for which all the components required for documenting the design of the building.
Reddy (2012)	An improvement methodology process that leverages data to analyse and predict outcomes through different phase of the building life-cycle.
Newman (2013)	A process of generating and managing building data during a structure's life cycle.

Based on the definitions mentioned in Table 2.1, it can be concluded that BIM is not just a technology, but it also encompasses the process by using product of the right kind of software (Azhar, 2011). BIM application connects all parties such as architects, contractors, surveyors, designers and owners to work together on a common information system (Eastman *et al.*, 2009). Thus, this allows all parties to share the information with each other and increasing the confidence and consistency among them.

2.3.2 The Concept of BIM

According to Smith (2007), the concept of Building Information Modelling is to build a building virtually, prior to building it physically, in order to work out problems, simulate and analyse potential impacts. The heart of Building Information Modelling is an authoritative building information model. While according to Kymmel (2008), virtual building implies that it is possible to practice construction to experiment and to make adjustments in the project before it is actualised. Virtual mistakes generally do not have serious consequences provided that is identified and addressed early enough that can be avoided in the actual construction of the project. When a project is planned and built virtually, most of its relevant aspects can be considered and communicated before the instructions for construction are finalised. It is like running a simulation of construction project by considering all aspect of construction life cycle (Kymmel, 2008).

The types of data that can be derived from Building Information Model, Elvin (2007) explain that Building Information Model could provide 2-D and 3D drawing with no graphical information including specifications, cost data, scope data, and schedules. Most importantly, it creates an object-oriented database, for example, representation of doors, windows, and walls which capable of storing both quantitative and qualitative information about the project. Therefore, while a door represented in a 2D CAD drawing is just a collection of lines, in BIM it is an intelligent object containing information on its size, cost, manufacturer, schedule and more. But BIM goes beyond further by creating a relational database (Haron *et al.*, 2009). This means that all information in the BIM is interconnected, and when a change is made to an object in the database, all other affected area and objects are immediately updated. For example, if a wall is deleted, doors and windows within the wall are also deleted, and all data on project scope, cost, and schedule are instantly adjusted (Haron *et al.*, 2009). Figure 2.2 shows the conceptual diagram to describe the Building Information Modelling.



Figure 2.2: Conceptual Diagram to Describe the Building Information Modelling (Haron *et al.*, 2009)

2.3.3 Characteristics of BIM

Building information modelling solutions create and operate on digital databases for collaboration, manage change throughout those databases so that a change to any part of the database is coordinated in all other parts and capture and preserve information for reuse by additional industry-specific applications (Autodesk, 2002).

2.3.3.1 Digital Databases

Building information models organize collaboration by the building team through digital databases (Villaitramani, 2014). The building information model can be

distributed to individual team members working on a network or sharing files through project collaboration tools. Team members work independently on local datasets while the building information modelling solution manages changes to the model from each of these local databases in a central shared location. Team members can compare their work to concurrent work by other team members, dynamically reserve, and release portions of the database for use over the network. A record of these interactions that changed what and when is available for review and a history of all changes made by all team members can be preserved in the building information model for as long as this information is useful. Changes can be selectively rolled back to support investigations of options or changes in design direction (Autodesk, 2002).

2.3.3.2 Change Management

Change is an integral part of building design as the design process is iterative in nature and involves the exploration and analysis of many alternatives (Tory *et al.*, 2008). Changes are not limited to the design phase but often continue throughout the construction phase due to concurrency of design and construction, particularly on fast-track projects, or in order to remove inconsistencies and enhance quality. Studies have shown that 20 to 25% of the construction period is lost due to deficiencies in design and 78% of quality problems are attributable to design (Undurraga, 1996). Therefore, successful management of design changes is of vital importance for the efficient delivery of construction projects.

During such an iterative process, the content and structure of design information are not static but subject to continual changes. In this dynamic environment, information models that are developed to coordinate design changes must be as flexible and dynamic as the design process itself. This is a significant challenge in the development of computer-based information models.

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